BC hydro

A Project Rationale for the THIRD WILLISTON TO KELLY LAKE 500 kV TRANSMISSION LINE

November 1989

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The Third Williston to Kelly Lake 500 kV Transmission Line

Project Rationale

SYSTEM PLANNING DIVISION
SYSTEM DEVELOPMENT

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Executive Summary[1]

The purpose of this report is to outline B.C. Hydro's planning process for major transmission projects and to explain how that process led to the proposal for reinforcing the 500 kV electric transmission system between Williston Substation near Prince George and Kelly Lake Substation near Clinton. The focus of this report is a third 500 kV single circuit transmission line between those two substations. That additional line will enable the system to transmit the increased power flows south of Williston Substation from new generation in the northern part of the province. The next generation developments in that area are Alcan's Kemano Completion Project southeast of Kitimat, scheduled for January 1995, and B.C. Hydro's Site C Project on the Peace River near Fort St. John, possibly to be built in the late 1990s. The third 500 kV line between Williston and Kelly Lake substations is now scheduled for completion in late 1994 to enable the system to transmit the increased flow of electricity that will be generated at Kemano.

The Williston to Kelly Lake transmission system is the only link between northern generation and the major load centre in the southwest and the operation of that system does not now meet B.C. Hydro's electric system criteria. It is for this reason that B.C. Hydro currently relies on remedial action schemes to ensure continuity of electrical service during severe disturbances on that part of the transmission system. These remedial action schemes include the rapid reduction of generation north of Kelly Lake Substation for a disturbance on either of the two existing Williston to Kelly Lake 500 kV lines and large restrictions on northern generation output when one of the two lines is out of service for an extended period of time. The additional flow of electricity from new generation in the north will make the use of remedial action schemes inadequate for assuring reliable electrical service under all operating conditions. The addition of a third Williston to Kelly Lake 500 kV transmission line will be a sufficient system reinforcement to provide that reliability and there would also be sufficient transmission capacity to accommodate the additional electricity from Site C generation on the Peace River near Fort St. John if that project is constructed.

The Williston to Kelly Lake transmission line project is now the subject of a comprehensive public consultation and environmental study process. This process is intended to identify potential social and ecological impacts that could be caused by the construction and operation of the line and to determine ways of avoiding or mitigating those impacts.

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[1] There is a Glossary of Terms at the end of this report and many words and phrases in the main body of the report are referenced to the Glossary. In this Executive Summary and in the Introduction no such specific references are made.

1. Introduction

B.C. Hydro's mission is to support the economic growth of British Columbia through the efficient supply of electricity. As the loading on the 500 kV transmission system between Williston Substation near Prince George and Kelly Lake Substation near Clinton increases because of generation additions in the north, the first of which is scheduled to be Alcan's Kemano Completion Project southeast of Kitimat, it is imperative that this system be reinforced to maintain system reliability; that is, to maintain an assured supply of electricity.

This report outlines B.C. Hydro's planning process for major transmission projects and explains how that process led to the proposal to reinforce the Williston to Kelly Lake transmission system with a third 500 kV single circuit transmission line between those substations.

The following pages contain brief descriptions of:

- a typical electrical transmission system;
- B.C. Hydro's existing major transmission system;
- the electric load forecast for the next ten years;
- the resource plan to meet the growing electric load;
- the transmission planning process which determines what system reinforcements are needed; and,
- the third Williston to Kelly Lake 500 kV transmission line.

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2. Electrical Transmission Systems - What they are and how they are planned

Electric transmission systems are complex networks of transmission lines connecting generation resources that produce electricity to load[2] centres that consume electricity. This section summarizes information not only on the transmission lines but also on the various stations in which the lines terminate and on the equipment located in those stations. More technical detail can be found in the Glossary of Terms at the end of this report.

2.1 Elements of a Transmission System

Figure 1 is a schematic drawing of the basic elements of an electric power[2] system from the generation plant to an individual customer. The transmission elements of that system consist of the major transmission lines which transmit electric power directly from the resource to the large central substations which serve major load centres; the "area" transmission lines which take the power from the central substations to large industrial customers and to local area distribution substations; and the "distribution" lines which deliver the power from the distribution substations to smaller industrial, commercial and residential customers.

Major transmission lines typically operate at the highest voltages in the system while area transmission lines operate at intermediate voltages and distribution lines at the lowest voltages. B.C. Hydro's major transmission system consists of over 13,000 kilometres of lines operating at voltages from 500 kV [3] down to 138 kV.

The primary purpose of the major transmission system is to reliably[2] transmit electric power from remote generation resources to the major load centres. Maintaining adequate reliability requires that there be no loss of generation[2] or load during specified system disturbances[2].

Since the major generation resources in British Columbia are quite distant from the loads, high transmission voltages are required to economically transmit that power. Some of the key elements of the major transmission system are briefly described below.

Generators - The first component of any electrical system is the source of electricity; in this case, the generators at the hydroelectric power dams. The water in the reservoirs flows through turbines which turn the generators, producing electricity at a voltage which is typically between 10 kV and 20 kV. In an integrated electrical system, generators must rotate at constant relative speeds; that is, they must operate in synchronism[2] .All generators which are part of interconnected systems in Canada, the United States and Mexico rotate at constant speeds relative to each other.

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[2] See Glossary

[3] Kilovolt (kV) or thousand volts, the operating voltage of the line; see Voltage in Glossary.

Transformers - Transformers[4] are used to change transmission line voltages from one level to another. Generators produce electricity at low voltages. Transformers raise this low voltage to a higher voltage (up to 500 kV in the B.C. Hydro system) for efficient transmission over long distances to the load centres. Transformers are also used in substations (see below) to transform the major transmission voltages down to area transmission and distribution voltages.

High Voltage Major Transmission Lines - The high voltage electricity from the generation stations is transmitted to the major load centres over the major transmission lines. These high voltage lines (500 kV and 230 kV) can transmit more power over longer distances than lower voltage lines and can do so with lower power flow losses[4]

Substations - Substations interconnect transmission circuits and may include transformers for changing voltage levels. These stations also contain circuit breakers[4] and other equipment necessary to disconnect failed lines or transformers from the system.

Series Capacitors - Series capacitors [4] are inserted into transmission lines to increase the amount of electricity that can be transmitted.

2.2 Planning a Major Transmission System

System transmission planning involves technical and economic studies to determine the best way to reinforce the system to accommodate increases in load and generation. The selected plan should be flexible enough to cover some of the uncertainties associated with such factors as the cost of money, load growth rates and the resource plans. A significant part of the work of planning the transmission system north of Kelly Lake Substation is concerned with ensuring that all generators remain in synchronism (continue to rotate at constant relative speed) during normal and emergency conditions.

Technical Studies

An electric power system is technically complex and computer simulation studies must be conducted to predict its behaviour under specific conditions. The results of these studies are used both for operating the existing system and for determining future requirements.

Power flow[4] studies provide information on such power system quantities as electric currents[4] , voltages[4] , power flows and power flow losses.

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[4] See Glossary.

Transient stability[5] studies provide information on the dynamic behaviour of the system during the first few seconds following a disturbance. These studies determine quantities such as the rotational speed of each generator, electric current flowing through the windings of each generator and the voltage at each generator terminal.

The technical studies revealed that the primary factor limiting the transmission capability between Williston and Kelly Lake substations is transient stability.

Economic Studies

The economics of different transmission system expansion plans are analyzed using discounted cash flow[5] methods. Economic assessments compare options by considering: capital costs, interest during construction, corporate overhead, the expected useful lifetime of each component, expected annual operating and maintenance costs, taxes, power flow losses, inflation and interest rates.

2.3 Transmission Planning Criteria for the Williston to Kelly Lake Line

This section summarizes those planning criteria used by B.C. Hydro[6] which are relevant to the planning of the Williston to Kelly Lake transmission system.

For example, B.C. Hydro has developed certain planning criteria to provide reasonable margins for transient stability under stressed conditions such as high generation output. Transient stability is a measure of electric power system performance which indicates the system is capable of withstanding a disturbance with no generators losing synchronism. Transient instability can result in widespread blackouts caused by cascading [5] tripouts[5] .

Also, lines must be operated to maintain minimum safe conductor-to-ground clearances. As conductors heat up they get longer and conductor-to-ground clearances are reduced. Because electric current flow increases conductor temperature, transmission line capacity can be limited by ground clearance considerations during hot summer weather.

In general, B.C. Hydro's major transmission system must continue to operate properly when a single element of the system fails (e.g., a transmission line). It must withstand this loss during the high stress condition of the generating plants north of Kelly Lake Substation operating at maximum output. Under these conditions the system must meet the following performance standards:

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[5] See Glossary

[6] Transmission Planning Criteria, B.C. Hydro Report No. SP 8707, July 1987.

- no loss of load[7]
- no loss of generation
- no loss of synchronism (i.e., must remain transiently stable)
- no overloading[7] of transmission system equipment
- voltages remain within acceptable limits

As a member of the Western Systems Coordinating Council (WSCC)[7] , B.C. Hydro must demonstrate that a disturbance within the B.C. Hydro system will not spread to the systems of neighbouring utilities.

3. The Existing Major Transmission System

Figure 2 is a schematic map of the existing B.C. Hydro major transmission system. The primary generation resources are in the north on the Peace River and in the southeast on the Columbia River system. The largest load centre is in the Lower Mainland and on Vancouver Island. As can be seen in Figure 2, most of the major transmission lines are routed from the hydroelectric generating plants in the north and southeast to the load centre in the southwest corner of the province. Electricity generated on the Peace River flows south through Williston Substation to Kelly Lake Substation. The additional electricity that will come from Alcan's Kemano Completion Project southeast of Kitimat will enter Williston Substation from the west and from there flow south to Kelly Lake Substation. The Williston to Kelly Lake transmission system is the only link between northern generation and the major load centre in the southwest.

4. The Load Forecast

The most significant factor in determining when new generation and transmission facilities are needed is the forecast of future electrical load. Figure 3 shows the 1989 load forecast for the next ten years. This forecast was developed as a range of "possible futures" based on such factors as expected population growth, future energy [7] prices and various economic development forecasts for the province.[8] The Probable forecast of 2.8% average load growth per year for the next 10 years is represented by the middle line in Figure 3. The Probable forecast is the 50th percentile. That is, there is a 50% chance the actual load will be at or below the Probable forecast. There is a 95% chance the actual load will be at or below the levels represented by the 95th percentile forecast.

5. The Resource Plan

As the load grows, resources must be developed to supply the required additional power. Each year a resource plan is proposed based on the latest load forecast.

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[7] See Glossary.

[8] Historically, there has been a close correlation between growth of Gross Provincial Domestic Product and growth in electrical demand. While there is no reason to believe that this historical relationship will continue indefinitely, there is also no reason to expect a marked deviation over the forecast period.

Following are brief summaries of the new resources now scheduled for the next 10 or more years to provide electrical power for use by B.C. Hydro's customers. This schedule provides sufficient resources to meet the Probable forecast shown in Figure 3 and has the capability of advancing or delaying some developments if actual load growth is above or below the Probable.

Power Smart Programs - These are on-going, customer-oriented, energy efficient programs directed towards reducing future load growth by encouraging more efficient use of energy. This benefits both the customer (through lower electricity bills) and B.C. Hydro (by postponing the need for new generation facilities, thus lowering financial commitments and delaying environmental impacts).

Resource Smart Programs - These on-going programs are intended to make existing generation and transmission facilities more efficient and thereby obtain significant additional energy from the B.C. Hydro system and allow development of new facilities to be postponed.

Coordination and Purchases

Inter-Utility System Coordination

B.C. Hydro expects to implement a coordination agreement with the Bonneville Power Administration in the fall of 1989 and is discussing the possibilities for coordination with Alberta utilities.

Alcan Purchase[9]

B.C. Hydro has agreements in principle with Alcan for coordinated reservoir operation for fifty years and for the purchase of 2500 GW.h[10] per year for twenty years, both beginning in early 1995 when Alcan's Kemano project, southeast of Kitimat, will be completed.

These coordination and purchase agreements offer B.C. Hydro a potentially attractive combination of flexible supply and fairly priced energy.

Independent Power Producers - In the future, B.C. Hydro will be relying more on independent power producers and increased self-generation as a way of minimizing the cost of electrical service. Cost effective independent power production can contribute a portion of B.C. Hydro's supply requirements and allow deferral of more costly projects.

Downstream Benefits Arising from the Columbia River Treaty - The Canadian entitlement to downstream benefits resulting from the operation of water storage in the reservoirs at the existing Duncan, Keenleyside and Mica dams under the Columbia River Treaty was sold to the United States for a period of 30 years. Those downstream benefits will revert to British Columbia, starting in 1998/99.

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9 Alcan's generating capacity at Kemano is now about 900 MW (megawatts; see Glossary); Kemano Completion, now scheduled for early 1995, will increase that to a total capacity of 1420 MW.

10 Gigawatt hours (GW.h). See Watt Hour in Glossary.

Keenleyside Generation - Keenleyside is an existing storage dam on the Columbia River near Castlegar. Turbines would be installed in the dam to utilize the energy of the water behind the dam. The presently projected in-service date is 1998 with a generation output capacity of 240 MW (project size is currently under review).

Peace Site C - Site C, near Fort St. John, would be the third dam on the Peace River (W.A.C. Bennett and Peace Canyon dams near Hudson's Hope are already producing power). Public demand for electricity is growing at a rate which indicates that power from Site C, which is planned as a 900 MW development, could be required by 1999.

Additional Resources Beyond 2000 - Selection of the next possible resource addition to the system after Site C has not been made. The choice will be affected by actual load growth and load forecasts over the next few years, the return or sale of the Columbia River downstream benefits and by the effectiveness of the programs described above.

As can be seen from this list, resource options other than the development of large generating facilities are taking precedence in the preparation of the Resource Plan. However, Alcan's Kemano Completion Project is the first large development being built and the transmission system must be adequate to transmit power from that resource south to the major load centre while maintaining a stable and reliable system.

6. Major Transmission Planning North of Kelly Lake Substation

The generation capacity installed north of Kelly Lake Substation, which includes Alcan's existing Kemano development, has a major impact on the reinforcement requirements for B.C. Hydro's major 500 kV transmission system north of Kelly Lake. The distance from these northern generation plants to Kelly Lake is over 600 kilometres. For such long distances it is the transient stability of the system which limits the amount of power that can be transmitted. That is, the northern generators must remain stable following a severe disturbance on this portion of the system. Instability can lead to the electrical break-up of the system and wide spread power outages.

6.1 Existing System Restrictions

The transfer capability of the Williston to Kelly Lake portion of the major transmission system is now fully utilized. Two limitations of this part of the system are the conductor-to-ground clearances on the existing Peace 500 kV transmission lines and transient stability of the Peace River generators.

Conductor-to-Ground Clearance Restrictions - Recent surveys of the existing Peace 500 kV transmission lines have revealed that clearances between the electrical conductors and the ground severely limit output of the Peace River generators during hot summer weather. The Peace system is not adequate for expected future load growth and generating plant additions. Uprating the Peace transmission lines, including the two existing Williston to Kelly Lake 500 kV lines, is presently under way and will be completed by the fall of 1991.

Transient Stability Restrictions - When Peace River generation is at or near its maximum output of 3430 MW and a sudden outage occurs on one of the two existing Williston to Kelly Lake 500 kV lines, a fully loaded Peace River generating unit must be taken out of service quickly. This is necessary to avoid having all of the generation north of Kelly Lake Substation lose synchronism with the rest of the B.C. Hydro system. As well, whenever one of the two Williston to Kelly Lake 500 kV lines is out of service for an extended period, Peace River generation must be reduced to a maximum of 2600 MW. This avoids the risk of generators in neighbouring utilities losing synchronism if the one remaining 500 kV line is lost.

The Peace River 500 kV transmission system does not now meet the transmission planning criteria discussed in Section 2.3. That is, some Peace River generation must be taken out of service for a single 500 kV disturbance between Williston and Kelly Lake substations. The system must be reinforced to enable any additional power to be transmitted from Williston to Kelly Lake, the first of which is scheduled to come from Alcan's Kemano Completion Project.

6.2 Reinforcement Options

Two alternative system reinforcements between Williston and Kelly Lake substations were studied in detail:

A Third Williston to Kelly Lake 500 kV Transmission Line - This would complete the reinforcement of the Peace transmission system that was originally contemplated when the Peace Canyon hydroelectric project near Hudson Hope was being planned. The third line would be physically similar to the existing two 500 kV lines which now connect Williston and Kelly Lake substations. This project would also include a series capacitor bank installed at the existing McLeese Capacitor Station located north of Soda Creek near the mid-point of the line. (Fig.2)

This reinforcement in 1994 would provide enough additional capacity to transmit electricity from the Kemano Completion Project and would satisfy all the criteria in Section 2.3. There would also be sufficient transmission capacity to accommodate an additional 900 MW of electricity from Site C generation on the Peace River near Fort St. John if that project is constructed.

Increase Series Compensation for the Two Existing 500 kV Lines -This would involve adding series capacitors to those already in the two existing lines at McLeese Capacitor Station. The effect would be to increase the transmission capacity of the existing lines. Reinforcing the system by adding more series capacitors would not satisfy the criteria summarized in Section 2.3.

After Kemano Completion generation output is added to the transmission loading south of Williston Substation, the loss of one of the two existing lines would overload the remaining line. It is not practical to attempt to increase the current carrying capacity of the two existing Williston to Kelly Lake 500 kV lines so that either line alone could transmit full Peace plus Kemano output. Such an effort would entail uprating equipment not only at McLeese Capacitor Station but also at Williston and Kelly Lake substations as well as replacing some or all of the towers on the two lines.

In any event, with one of the two Williston to Kelly Lake lines out of service, WSCC reliability criteria would limit northern generation such that B.C. Hydro would be unable to serve total load requirements.

6.3 Recommendations and Rationale

Based on Alcan's plan to develop their Kemano Completion Project by early in 1995 and on the need to satisfy B.C. Hydro's transmission planning criteria, the Williston to Kelly Lake transmission system will require reinforcement with a third 500 kV transmission line by late 1994. If new generation is developed north of Kelly Lake and the system is not reinforced, loss of one of the two existing 500 kV lines would require a reduction in generation output north of Kelly Lake in order to maintain transient stability and B.C. Hydro would be unable to serve peak load [11] demands.

The total estimated capital cost of the third Williston to Kelly Lake 500 kV transmission line is approximately $178 million. It would provide an effective means of reinforcing the system to accommodate the increased power flows from new northern generation. The two existing Williston to Kelly Lake lines are now among the most heavily loaded 500 kV lines in the major transmission system. The new line would maintain system reliability and greatly reduce system losses which would cover, (over its operating lifetime) approximately 75% of the total capital and operating costs associated with the line, based on forecast energy costs and expected power flows.

7. The Third Williston to Kelly Lake 500 kV Transmission Line

7.1 Background

Electricity was first generated at the powerhouse within the W.A.C. Bennett Dam on the Peace River near Hudson's Hope in 1968. That electricity was transmitted on two 500 kV transmission lines connecting the powerhouse to Williston Substation near Prince George, then to Kelly Lake Substation near Clinton and finally to the load centre in the Lower Mainland. Those two lines, together with the intermediate substations and series capacitor stations, were capable of reliably transmitting the ultimate 2730 MW capacity of the Bennett Dam development and were the first 500 kV transmission lines in British Columbia.

In 1979, 700 MW of additional generation were developed on the Peace River at Peace Canyon Dam, a few kilometres downstream of the W.A.C. Bennett Dam. In order to satisfy planning criteria following this addition, transmission reinforcement was required between the Peace River generation plants and Kelly Lake Substation. A third line was built from the Peace River to Williston Substation but the third Williston to Kelly Lake 500 kV line was deferred because of fiscal restraint.

In 1981, an Application for an Energy Project Certificate for the Site C generation project on the Peace River near Fort St. John was submitted to the provincial Minister of Energy, Mines and Petroleum Resources. Included in that Application was the requirement for a third 500 kV transmission line between Williston and Kelly Lake substations. Site C was not approved at that time and the third Williston to Kelly Lake line was again deferred.

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[11] See Glossary.

7.2 Project Description

The new line is planned as a single circuit, 500 kV steel tower transmission line, approximately 330 kilometres long, essentially the same as the two existing 500 kV lines between Williston and Kelly Lake substations. Both self-supporting and guyed structures (Fig. 4) will be used. A series capacitor bank will be installed near the mid-point of the new line at the existing McLeese Capacitor Station north of Soda Creek.

Sufficient right-of-way was acquired for the third Williston to Kelly Lake 500 kV line when the first two 500 kV transmission lines were built in the 1960s. The third line will be located east of and adjacent to the existing lines (Fig.5). Clearing will be necessary along the full length of the new line but only minimal additional right-of-way will be needed at specific locations along the route.

7.3 Project Studies and Schedule

Environmental studies now in progress will include assessments of the potential ecological and social impacts of the third 500 kV line and recommendations for avoiding or mitigating those impacts. These studies are being coordinated closely with the engineering studies which are concerned with the security and cost implications of the various mitigation alternatives. The findings from these studies will be shared and discussed with the various levels of government and the general public.

Figure 6 is an outline of the project schedule required to meet the proposed late 1994 in-service date. The schedule is shown in two phases. Phase 1 covers public consultation and route studies. Phase 2 covers design and construction activities.

B.C. Hydro applied to the Minister of Energy, Mines and Petroleum Resources in September of 1989 for approval to build this third line so there will be some assurance that B.C. Hydro will have access to a new large generation resource to help supply the growing domestic demand for electricity and so Alcan will have a market for their surplus electricity. There will be no reduction in the public consultation process nor in the environmental impact studies for the line because of this early application. Local route adjustments and construction considerations will still be taken into account to eliminate or reduce impacts.

Glossary of Terms

Alternating Current (AC) is electric current which alternates its direction of flow periodically. The electricity supplied to homes in North America alternates at a frequency of 60 cycles per second or Hertz (Hz).

Ampere (A) or Amp is a unit for measuring electrical current flow. The current that flows in a typical 100 Watt household light bulb is about one ampere. Very high currents are measured in kiloamperes or kiloamps (abbreviated as kA). One kiloamp is equal to one thousand amps.

Capacitors are connected together in series and parallel to form the large capacitor banks used in electric power systems. Capacitor banks are connected in series with transmission lines to reduce transmission system impedance (see below). They are also connected in "shunt" (i.e., between a live conductor and the ground or between live conductors) to help raise system voltages.

Cascading refers to multiple tripouts of generators and transmission system equipment caused by the loss of one or more elements which results in the subsequent overloading and tripping out of other equipment which in turn causes further overloading and tripouts.

Circuit Breakers are fast switches used to interrupt electric current flow. The extra high voltage (EHV) circuit breakers used in major transmission network substations are capable of interrupting electrical current of tens of thousands of amperes.

Current (see Alternating Current and Amperes) is the flow of electrons in electrical equipment such as transmission lines. Electric current is measured in units called amperes.

Discounted Cash Flow is a method of economic analysis which takes proper account of interest and inflation rates when determining the total value of a series of expenditures and earnings over a period of time.

Electric Energy (see also Watt Hour) is the amount of electricity produced, transmitted or consumed in a given period of time. A 100 watt light bulb consumes 100 watt hours of electricity for each hour it is turned on.

Electric Power (see also Watt) is the rate at which electrical energy is produced, transmitted or consumed, measured in watts.

Energy (see Electric Energy)

Gigawatt hours (GW.h) (see Watt Hour)

Impedance is the property of a conductor or circuit which resists the flow of an electric current.

Kilovolts (kV) (see volt)

Load is the electric power or energy used by electrical devices connected to a power system.

Loss of Generation is the separation of one or more generating units from the main power system due to loss of synchronism, generator dropping or manually opening the generator circuit breakers.

Loss of Load is the quick, automatic or manual, disconnection from the electric system of devices that use electricity.

Losses (see Power Flow Losses)

Megawatts (MW) (see Watt)

Overload is a condition in an electric circuit where one or more elements are subjected to higher than their rated operating levels of current or voltage.

Peak Load or peak power demand is the highest level of power consumption (usually measured in megawatts) experienced by a power system in a given period of time (e.g., day, month, season or year).

Power (see Electric Power)

Power Flow refers to the amount of electricity being transmitted on a transmission line or flowing through transformers and other electrical devices.

Power Flow Losses are energy losses in electric power systems which result from the heating caused by the flow of electric current.

Reliability is a measure of the continuity of electric service over a long period of time.

Series Capacitors (see Capacitors)

Stressed Condition refers to a situation in a power transmission system during which it is operating at or near its transfer capability limit. In many cases stressed conditions involve peak loads and maximum generation levels.

Synchronism is an operating condition where the rotational speed of a generator or group of generators is exactly proportional to the frequency of the power system (60 Hertz or cycles per second in North America).

System Disturbance is an occurrence, such as lightning or avalanche, which causes some element of the transmission system to suddenly be taken out of service.

Transformers are devices used for changing or "transforming" electricity from one voltage level to another.

Transient Stability is an operating condition whereby, after a specified system disturbance, a generator or group of generators will, within about one-tenth of a second, return to pre-disturbance rotational speed.

Tripout (see also Cascading) is the disconnection of a power system element (e.g., transmission line, transformer, generator, etc.) by the action of circuit breakers usually initiated automatically by protective relaying equipment.

Volt (V) is the unit for measuring voltage (see below). Very high voltages are measured in kilovolts (abbreviated as kV). One kilovolt is equal to one thousand volts.

Voltage (see also Volt) is the electric "force", measured in volts, which causes current, measured in amperes (see above), to flow in electrical circuits.

Watt (W) is the unit for measuring electrical power or the rate of generating, transmitting or consuming electricity. High levels of electric power are measured in kilowatts (abbreviated as kW), megawatts (MW), and gigawatts (GW). One gigawatt is equal to one thousand megawatts. One megawatt is equal to one thousand kilowatts and one kilowatt is equal to one thousand watts.

Watt Hour (W.h) is the unit of measure for electrical energy or work. A 100 watt light bulb operating continuously for ten hours will consume one thousand watt hours (or one kilowatt hour, kW.h) of electricity. A gigawatt hour is one million kilowatt hours.

WSCC - The Western Systems Coordinating Council is an organization of over 60 electric utilities in two western provinces of Canada, 14 western states of the United States and the northern portion of Baja California, Mexico. The WSCC provides a forum for the coordination of the planning, design and operation activities of its member utilities. The WSCC is one of nine regional councils which comprise the North American Electric Reliability Council (NERC). The function of NERC is to coordinate, promote and communicate reliability matters for North America's electric utilities.

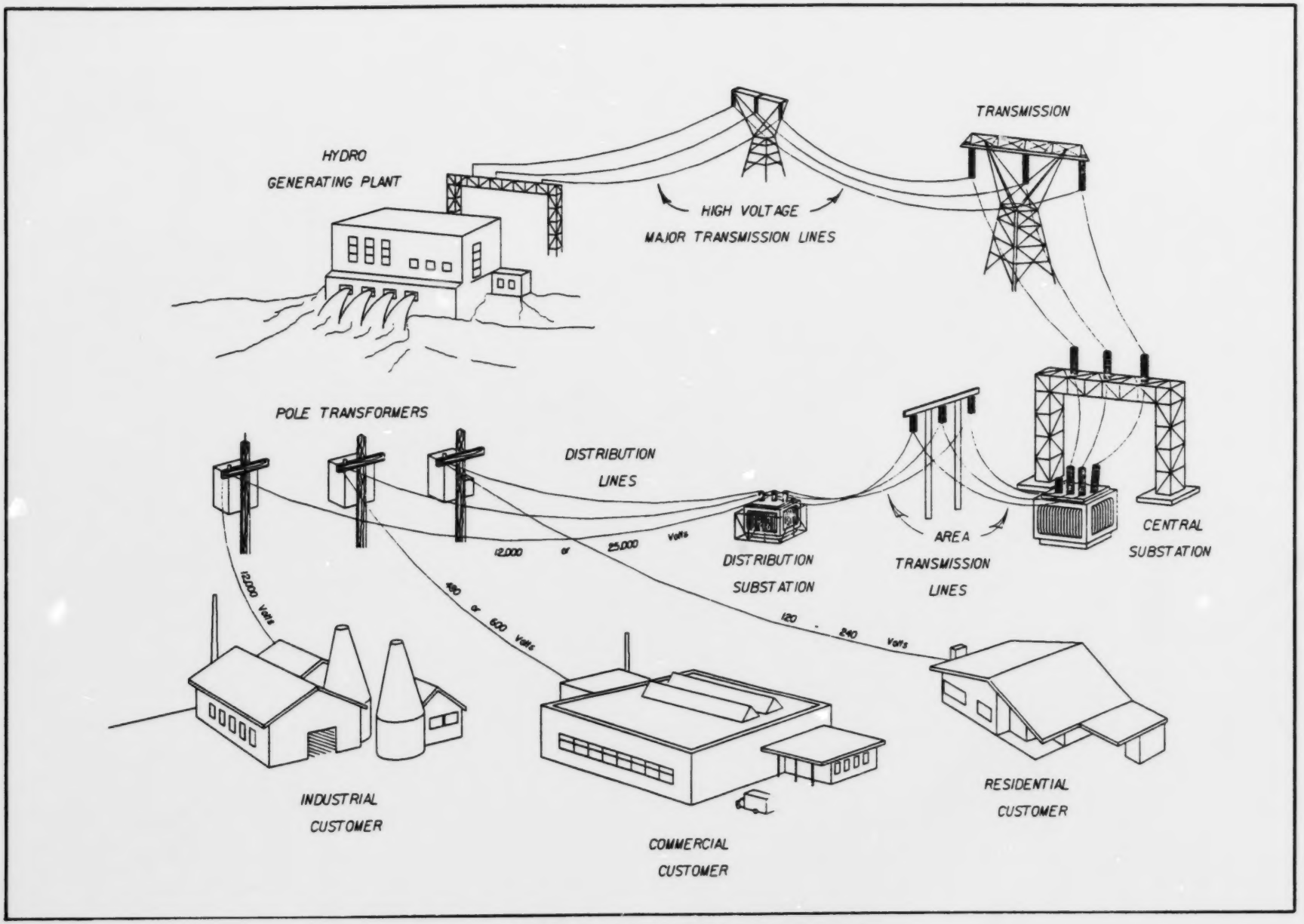
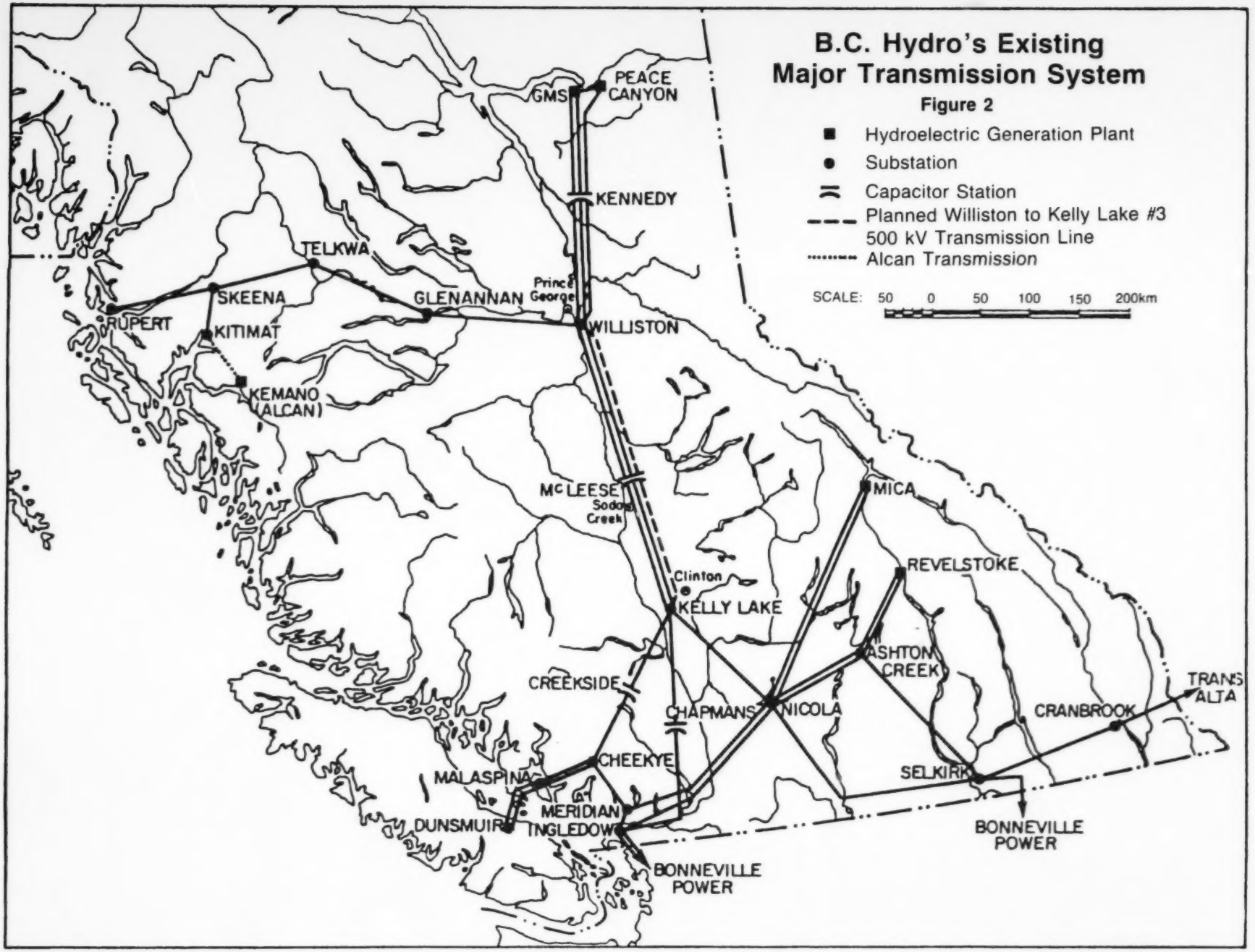


FIGURE 1 - BASIC ELEMENTS OF A POWER SYSTEM


B.C. Hydro's Existing
Major Transmission System
Figure 2
Hydroelectric Generation Plant
Substation
Capacitor Station
Planned Williston to Kelly Lake #3
500 kV Transmission Line
Alcan Transmission
SCALE: 50 0 50 100 150 200km
PEACE CANYON
GMS
KENNEDY
TELKWA
SKEENA
GLENANNAN
Prince George
RUPERT
KITIMAT
WILLISTON
KEMANO (ALCAN)
McLEESE
Sodoma Creek
MICA
REVELSTOKE
Clinton
KELLY LAKE
ASHTON CREEK
CREEKSIDE
CHAPMANS
NICOLA
CRANBROOK
TRANS ALTA
CHEEKYE
MALASPINA
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BONNEVILLE POWER

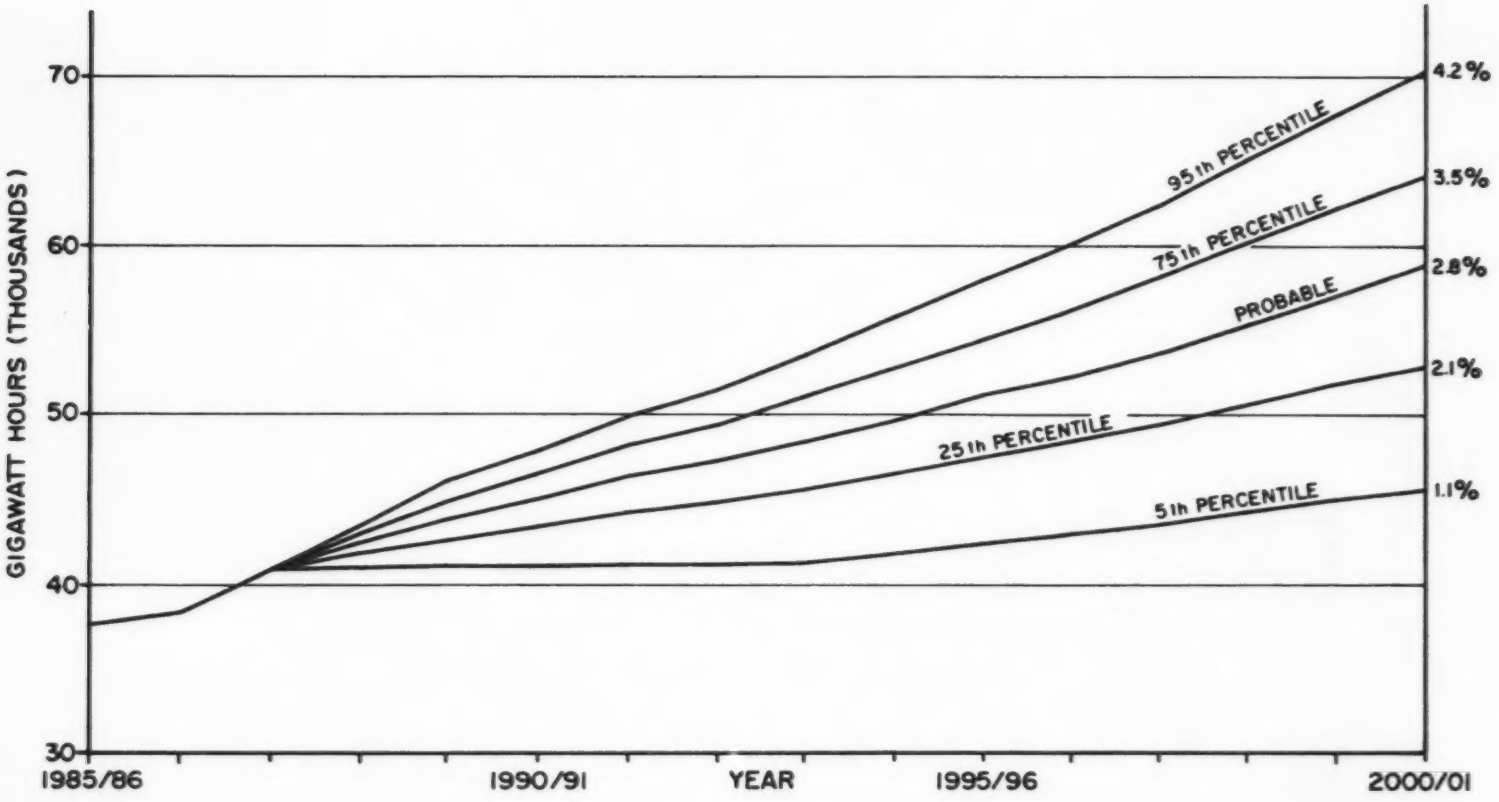
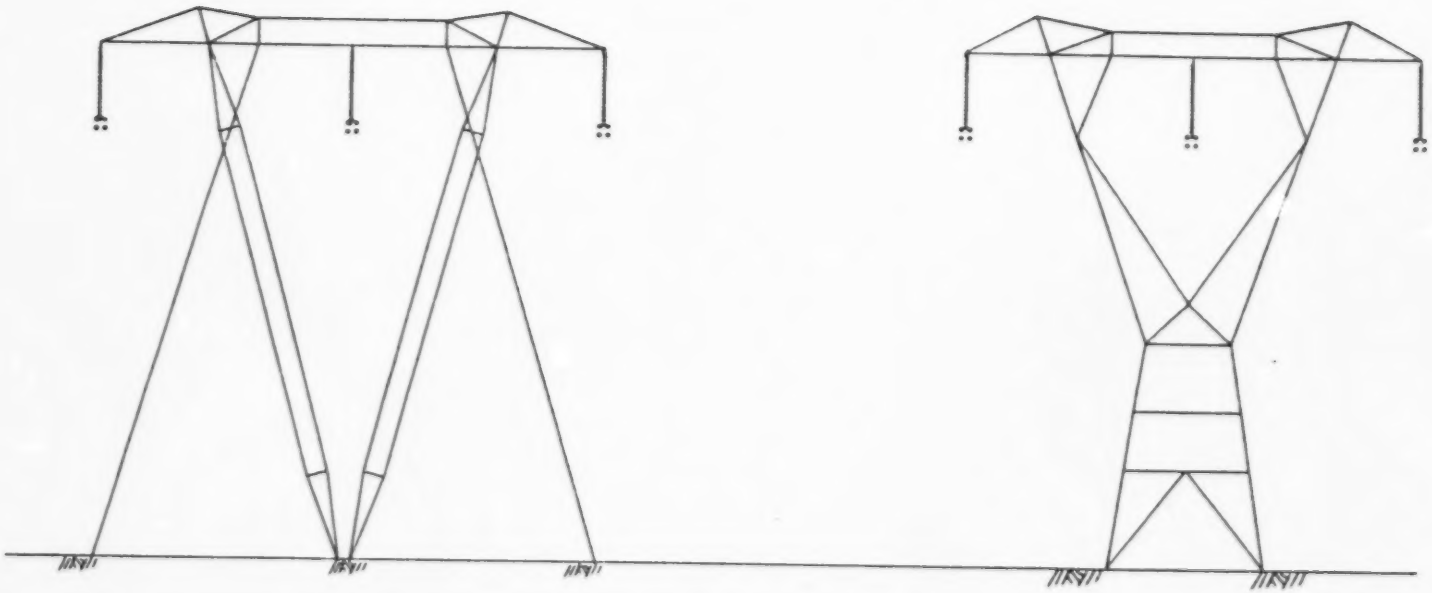


FIGURE 3

B.C. HYDRO ELECTRIC LOAD FORECAST

Williston — Kelly Lake
500 kV Transmission Project
Basic Structure Types

Figure 4

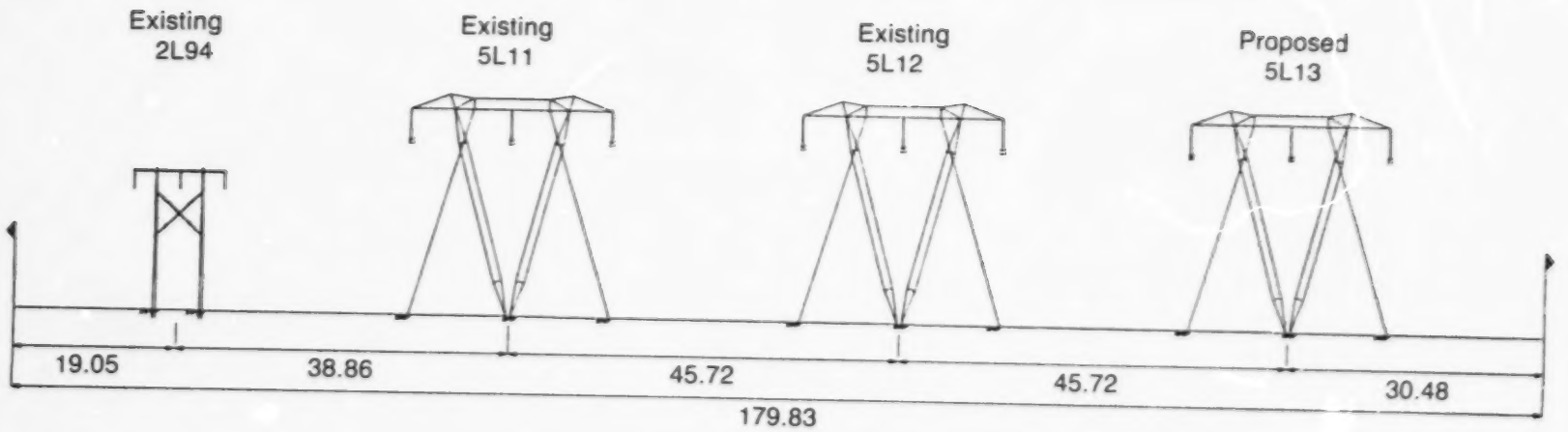


Typical Guyed Structure

Typical Rigid (Self Supporting) Structure

Williston — Kelly Lake
500 kV Transmission Project
Typical Right-of-Way Cross Section

Figure 5

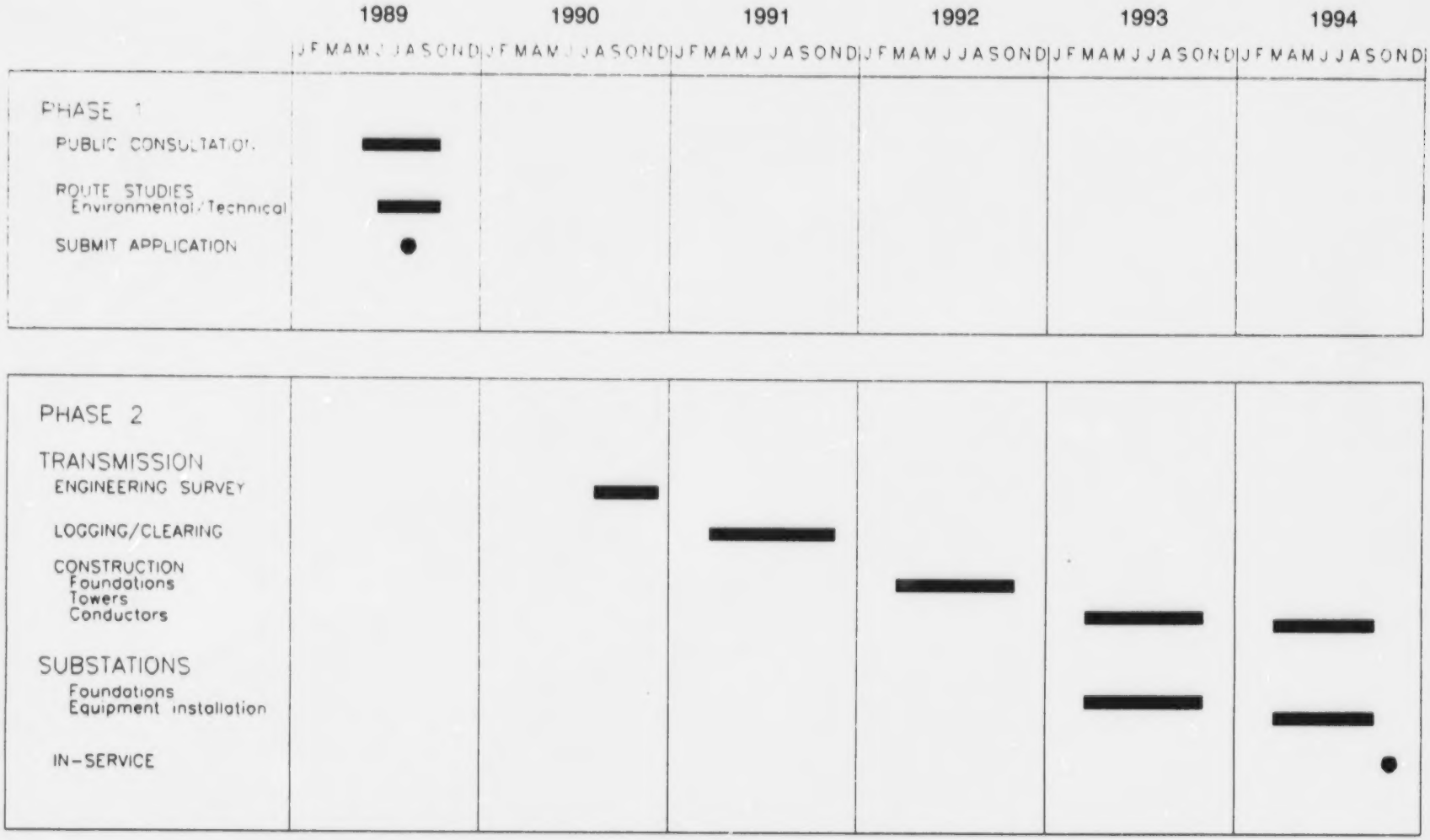


Looking North Towards Williston Substation

NOTE: Dimensions in metres

Williston — Kelly Lake
500 kV Transmission Project
Proposed Project Schedule

Figure 6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1990
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1993
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Towers
Conductors
SUBSTATIONS
Foundations
Equipment installation
IN-SERVICE